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Specification

Method for Analyzing the Color Deviations in Images Using an Image Sensor

The invention relates to methods using an image sensor for analyzing color deviations in images in accordance with the preambles of claims 1 or 2.

The trichromatic model mostly used in technology for describing additive color images is the RGB model. By means of the RGB model, the image space is described by the three basic colors red, green and blue. It is particularly disadvantageous in connection with this model that the description performed by means of the RGB model does not correspond to the perception of the human eye, since the reaction of the human perception, i.e. the detection through the sensory organs, is not taken into consideration.

DE 44 19 395 A1 discloses a method for analyzing color images by means of an image sensor, whose image signals are analyzed pixel by pixel. In the process the image signals are separated in accordance with colorfulness and brightness.

DE 692 24 812 T2 describes a method for image processing, wherein RGB signals are non-linearly transformed into color signal values L, C1, C2.

A method for classifying color images by means of fuzzy logic is known from DE 198 38 806 A1.

The object of the invention is based on creating methods using an image sensor for analyzing color deviations of images.

In accordance with the invention, this object is attained by means of the characteristics of claim 1 or 2.

Three cone types, which absorb in different spectral ranges, exist in the human eye. The maximum absorption of the S-cone type lies in the blue range, namely at 420 nm, the M-cone type absorbs maximally in the green range, namely at 534 nm, and the L-cone type has its absorption maximum at 564 nm in the yellow/red spectral range. Seeing by means of three types of cones is called trichromatic vision. The individual color perception is triggered by different excitation strengths of the individual cone types. Identical excitation of all cones leads to the perception of the color white. However, by means of the trichromatic vision model it is not possible to explain color perception phenomena, such as color antagonism and color constancy, for example.

Color antagonism means that defined colors can never be seen in transitions, so that no color transition between these colors is possible. Colors which show color antagonism are called compensation or complementary colors. The color pairs red/green and blue/yellow, as well as black/white should be mentioned here.

With color constancy, the different spectral distribution of the light, which for example is a function of the weather or daylight conditions, is compensated.

Hering developed the compensation color theory in 1920 in order to explain these color perception phenomena in a way different from the classic trichromatic color model. The compensation color model assumes that the cones are arranged in receptive fields, namely in blue/yellow fields and

red/green fields. Receptive fields are here understood to be neurons, and the manner in which the light signals coming from the cones are further processed by the neurons. Substantially two types of receptive fields are responsible for color vision. The first receptive field obtains its input from the L- and M-cones, the second receptive field from the S-cones, together with differently weighted signals from the L- and M-cones. It is assumed that subtractive color mixing of the excitations of the cones is performed in the plane of the neurons or receptive fields.

In the process for analyzing color deviations of printed images, the image signal received from the image sensor is analyzed pixel by pixel in a manner known per se. In accordance with the invention, the image signal is recorded by the image sensor in three color channels, which are separated from each other, for reproducing the three cone types in the human eye with their different spectral sensitivities. Each one of the three color channels has a characteristic spectral sensitivity. The two receptive fields representing the second stage of color processing in human vision are simulated by an appropriate linkage of the image sensor signals of the three color channels, which are separated from each other. In the technical model, the red/green field of human color perception represents the first compensation color channel. The output signal of the first compensation color channel is generated by the linkage of the image sensor signal of a first color signal with the image sensor signal of a second color signal. Linkage is performed by means of a calculation specification consisting of at least one arithmetic rule. In the technical model, the

blue/yellow field is generated by linking the image sensor signal of a third color channel with a combination of the image sensor signals of the first and second color channel. In the technical model, the blue/yellow field corresponds to the second compensation color channel. The output signal of the second compensation color channel is generated by means of the above described linkage. Linkage is performed by means of a second calculation specification consisting of at least one arithmetic rule. A classification of the output signals from the two compensation color channels takes place in the next step for evaluating the examined pixel. It is decided by means of this whether the image content of the examined pixel corresponds to a defined class, by means of which an acceptable/unacceptable classification can be made.

It is without great importance for the principle of the invention in which spectral range the three color channels of the method are located, as long as these are color channels which are separated from each other. A preferred embodiment of the invention consists in that the three color channels correspond to the basic colors of the RGB model, namely red, green and blue. This has the advantage that it is possible to use a widely distributed color model.

To match the spectral sensitivity of each color channel to the spectral perception of the corresponding cone of the retina of the human eye, it is useful if the spectral sensitivity of every color channel can be matched to spectral sensitivities of the cones.

It is of secondary importance for the principle of the invention in which way the two output signals of the compensation color channels are generated. One possibility

consists in that one arithmetic rule of the first calculation specification provides the formation of a weighted differentiation between the image sensor signals of the first color channel, and/or an arithmetic rule of the second calculation specification provides the formation of a weighted differentiation between the weighted sum of the image sensor signals from the first and second image sensor channels and the third color channel.

In accordance with a further preferred exemplary embodiment of the invention, at least one signal in at least one compensation color channel is subjected to a transformation specification, in particular a non-linear transformation specification, after and/or prior to the linkage. A transformation has the particular advantage that the digital character of electronically generated recordings can be taken into consideration. By means of the transformation specifications it is also possible to transform a signal from the color space into a space in which the excitation of the cones can be described. In many exemplary embodiments the signals in both compensation color channels are subjected to a transformation.

Since with human vision the receptive fields are characterized by a low pass behavior, it is useful if at least one signal in at least one compensation color channel is filtered by means of a low pass filter. In accordance with a particularly preferred exemplary embodiment, the output signal of each compensation color channel is filtered by means of a low pass filter.

In accordance with a particularly preferred exemplary embodiment, the method has a learning mode and an inspection

mode. In the course of the learning mode, at least one reference image is analyzed pixel by pixel, and the output signals from the two compensation color channels created by the reference image are stored in a reference memory. This means that the image content of the reference image is actually recorded in three color channels, that the image signals of each color channel are matched in accordance with perception, and are subsequently linked with each other in accordance with the compensation color model. Then the output signals from each compensation color channel are stored pixel by pixel in the reference data memory. In the subsequent inspection mode, the output signals from the appropriate pixel generated by a test image are compared with the corresponding value in the reference data memory, and a classification decision is made.

In order to take permissible fluctuations of the image content, as well a fluctuations of the conditions during the image recording, into consideration, it is useful if the values stored in the reference data memory are formed by analyzing several reference data sets, so that for each value in the reference data memory a permissible tolerance window is fixed, within which an output signal value of a compensation color channel generated during the image inspection can fluctuate. In this case the reference variable of the output signal of a compensation color channel can be determined, for example, by means of forming the average arithmetic value of the individual values resulting from the reference data sets. The tolerance window can be determined, for example, from the minimum and maximum values, or from the standard deviation of the output signals of the

compensation color channels generated from the examined reference images.

Exemplary embodiments of the invention are represented in the drawings and will be described in greater detail in what follows.

Shown are in:

Fig. 1, a schematic representation of the method for analyzing color deviations in print images with a compensation color model,

Fig. 2, a flow chart of the learning and inspection mode.

As can be seen in Fig. 1, the recording of the image signals by an image sensor takes place in three color channels 01, 02, 03, which are separated from each other. In the present exemplary embodiment, the color channels 01, 02, 03 are the color channels red 01, green 02 and blue 03. Each one of the color channels has an adjustable spectral sensitivity. This has the advantage that the characteristic of each color channel 01, 02, 03 can be matched to the conditions of the existing set of problems. Thus it is possible, for example, to match the spectral sensitivity of a color channel 01, 02, 03 to the spectral sensitivity of the appropriate cone of the retina of the human eye.

In the method in accordance with the invention, the spectral content of an image is analyzed pixel by pixel. For modeling the two receptive fields red/green and blue/yellow of the human eye, the image sensor signals of the color channels 01, 02, 03 are linked with each other by means of the method of the invention. Prior to the actual linkage by means of the calculation specifications 04, 05, each image

sensor signal in the compensation color channel 07, 08 is subjected to a non-linear transformation 09. The digital character of the electronically generated recordings is taken into consideration by this. Subsequently, each signal is weighted with a coefficient K_i ($i = 1 \ldots 4$). By means of this it is achieved that a pure intensity change of the initial image does not provide a contribution to one of the output signals 12, 13 of the compensation color channels 07, 08. The generation of the output signals 12, 13 of the compensation color channels 07, 08 takes place analogously to the generation of the signals of the receptive fields in the human retina. This means that a linkage is performed by means of the calculation specifications 04, 06 of the color channels 01, 02, 03 corresponding to the linkage of the cones of the human retina. For creating the output signal 12 of the red/green compensation color channel 07, the image sensor signals of the red color channel 01 and the green color channel 02 are linked with each other by means of the first calculation specification 04. For generating the output signal 13 of the blue/yellow compensation color channel 08, in the present exemplary embodiment the image sensor signal of the blue color channel 03 is linked with the minimum 14 of the image sensor signals of the red color channel 01 and the green color channel 02 by means of the calculation specification 06. The receptive fields of the human retina are characterized by a low pass behavior. Accordingly, in the present exemplary embodiment the signal obtained by linkage are subjected to a low pass filtering process 16 with a Gauss low pass filter.

Fig. 2 shows the actual inspection of the printed products, which is performed in two stages, namely in a learning mode 17 and a downstream connected inspection mode 18. The aim of the learning mode 17 is the generation, pixel by pixel, of reference data values 19, which are compared in the subsequent inspection mode 18 with the output signals 12, 13 of the compensation color channels 07, 08 of the appropriate pixels. In the learning mode 17, the image contents of one reference image 21, or of several reference images 21, are analyzed in that the image contents of each pixel are entered into three color channels 01, 02, 03 and a subsequent adaptation in respect to perception of the image signals of each color channel 01, 02, 03 is performed, and thereafter further processing of the image sensor signals in accordance with the above described compensation color method is performed. Then the output signals 12, 13 of the compensation color channels 07, 08 obtained for each pixel are stored in a reference data memory. It is useful for also taking into consideration permissible fluctuations of the reference images 21, if several reference images 21 are considered in the learning mode 17. Because of this it is possible for the reference data values 19', 19'' of each pixel stored in the reference data memory to have a defined permissible fluctuation tolerance. The fluctuation tolerance can be determined either by minimum/maximum values, or from the standard deviation of the obtained data of the image contents of the reference images 21 of each pixel.

Then, in the inspection mode 18, a comparison, pixel by pixel, of the output values 12, 13 of the compensation color

channels 07, 08 of an inspection image 22 with the reference data values 19', 19'' from the reference data memory takes place. The comparison can be performed by means of a linear or non-linear classifier 23, in particular by means of threshold value classifiers, Euclidic distance classifiers, Bayes classifiers, fuzzy classifiers, or artificial neuronic networks. Subsequently an acceptable/unacceptable decision is made.

List of Reference Symbols

01	First (red) color channel
02	Second (green) color channel
03	Third (blue) color channel
04	First calculation specification
05	-
06	Second calculation specification
07	First (red/green) compensation color channel, first new color channel
08	Second (blue/yellow) compensation color channel, second new color channel
09	Non-linear transformation
10	-
11	Coefficients K_i ($i = 1 \ldots 4$)
12	Output signal of the first (red/green) compensation color channel, output value
13	Output signal of the second (blue/yellow) compensation color channel, output value
14	Minimum of the red and green color channel
15	-
16	Low pass filter
17	Learning mode
18	Inspection mode
19	Reference data values
20	-
21	Reference image
22	Inspection image
23	Classifier, classifier system

19'	Output signal, reference data value
19''	Output signal, reference data value